CAPACITIVE FORCE SENSING DEVICE

CLAIM OF PRIORITY

This application claims priority from the provisional application 60/461,528 filed on April 09, 2003 and incorporates said provisional application herein by reference

ABSTRACT

An exemplary capacitive force sensing device using springs of certain shapes as spacers between the dielectric plates.

FIELD OF THE INVENTION

The present invention pertains generally to improvements in the design of a parallel plate capacitive force sensing device solving several of the attendant problems.

BACKGROUND OF THE INVENTION

A capacitive force sensing device is essentially built using two parallel plates separated at a certain distance by an elastic spring. As force is applied the spring deflects thus reducing the gap between the parallel plates. A reduction in the gap between the capacitor plates leads to an increase in capacitance. A capacitance meter detects the change in capacitance occasioned by the decreased distance between the plates. This change in capacitance can be calibrated precisely for various loads applied and can be used to determine the amount of force applied.

Capacitive force sensing devices suffer from several constraints which have limited their manufacturability and usefulness in real life applications. These constraints are known respectively as relaxation or creep, hysteresis, set, and off-axis loading.

When a constant load is placed on an elastic spring, the observed deflection is not constant, but rather it could decrease or increase gradually with time. This behavior is called respectively, relaxation or creep. Upon removal of the load, if the spring does not come back to its original position (before the load was placed), the spring is said to have "set". These properties, including set, are a result of physical (elastic or viscoelastic) and chemical (molecular structure) changes in the spring material. It is fundamental to the operation of a capacitive force sensing device that the deformation of the spring be constant over time, else the force calculations will vary and be unpredictable.

Hysteresis is another limitation inherent to the use of various springs. When there is a difference in spring deflection at the same applied load - during loading and unloading – the spring is said to have Hysteresis. Hysteresis could come about from set, creep, relaxation and friction. Hysteresis will have the effect of limiting the usefulness of the capacitive force sensing device. Specifically, the spring must consistently and repeatedly return to its original position as the load is applied or removed. Failure to do so will cause erroneous readings.

Off-axis loading occurs when the direction of the applied load is not along the initial axis of the sensor. Off-axis loading can cause the capacitive plates to become non-parallel and significantly impact the measured capacitance and hence the load. Referring to Fig. 1, Fig. 1, illustrates an example of off-axis loading. Force 110 is applied to platform 120. Since force 110 is along the initial axis of the sensor, the two capacitor plates 120 and 140 remain parallel. Referring to Fig. 1b, force 150 is applied in a manner, not along the original axis of the sensors 160 and 180. Consequently, plate 160 rotates to be perpendicular to the direction of force 150 and is no longer parallel to plate 180.

Many traditional springs such as helical springs or elastomeric springs (made from polymers, i.e. rubber or plastic) tend to suffer from all of the above constraints and consequently require special attention and design changes for building consistently accurate sensors.

DETAILED DESCRIPTION OF THE EMBODIMENTS.

Referring to Fig. 2 one embodiment of a capacitive force sensing device is constructed of a capacitance meter 210, two parallel capacitance plates 220 and 225 separated by a helical spring 230. The capacitance meter is connected via wires 240. Capacitance plate 220 is a fixed base member, whereas capacitance plate 225 is moveable. The force sensing device has a capacitance based upon the area of the dielectric characteristics of the air as well as the volume encompassed by capacitance plates 220 and 225. The basic capacitance formula is:

$$C=kA/d \qquad \text{EQ. 1}$$

Where $\boldsymbol{C}$ represents capacitance, $\boldsymbol{k}$ represents the dielectric of the material(s) between the plate 220 and 225, $\boldsymbol{A}$ represents the area encompassed by the plates, $\boldsymbol{d}$ represents the distance between the capacitance plates 220 and 225.

When a unknown load (i.e. force, weight, pressure, etc.) 250 is applied to capacitance plate 225, the spring contracts following the formula:

$$F=k_1\Delta d \qquad \text{EQ. 2}$$

Where $\boldsymbol{F}$ represents the force applied, $\boldsymbol{k_1}$ represents the characteristic of the spring, and $\Delta\boldsymbol{d}$ represents the amount of deflection. Thus by measuring the capacitance before and after unknown load 250 is applied; the force is easily determined,

Referring to Fig. 3, in another embodiment of the invention, the invention utilizes hollow conical metal Belleville spring, also known as a cone washer 340 which deflects both longitudinally 320 (along the axis) and transversely 360 (perpendicular to) the direction of unknown load 305. As shown in Fig. 3, the force sensing invention is identical, to the force sensing device in Fig. 2, except for cone spring 340. The use of the conical spring provides several substantial advantages. The metal Belleville spring has a large base compared to its height combined with a large flat top surface which makes it unlikely that the placed load will cause the capacitive plates to suffer off-axis loading thus becoming non-parallel. Further, metals tend to be less susceptible to set and creep than other materials.

Referring to Fig. 4, the invention replaces the single Belleville spring with a spring whose major characteristics are: the top and bottom surfaces a wide, but not as wide as the middle, that it's deflectable both longitudinally and transversely and the plane of traverse deflection does not connect with (or touch) either of the platforms. As force 405 is placed against capacitive plate 410 it causes longitudinal deflection 415 in spring 430. However at the points where spring 430 contact capacitive plates 410 and 460, transverse deflection 440 and 450 are negligible which reduces the problem of friction and therefore, hysteresis.

In another embodiment of the invention, the spring is created from Belleville springs placed base to base.

In another embodiment of the invention, the spring is perforated, slotted or combinations thereof.

Referring to Fig. 5, in lieu of one pair of base to base Belleville spring; more than one such spring can be used. Force 505 is applied to capacitive plate 510 which causes a deflection in both spring 520 and 530. At the point of contact with each other as well as the capacitive plates, there is almost no tranverse deflection. The transverse deflection occurs only at the pointed ends of spring 520 and 530 and are represented marked 540 and 550 respectively.

In another embodiment of the invention, multiple back to back Belleville spring combinations can be utilized between the fixed and moving platforms in order to increase the load measurement capacity.

We claim

1. A capacitive force sensing device comprising:

   a base member;

   a platform structure moveable relative to said base member in response to a force applied to said platform structure;

   a spacer positioned between said platform structure and said base member, said spacer having a spring constant which is substantially linear with respect to the amount of force applied over a deformable region of said spacer, said spacer being made of metal; said region being defined as the linear travel distance of said spacer;

   a variable capacitor having a first electrode affixed to said platform structure and a second electrode affixed to said base member, said first electrode and said second electrode having a nominal distance of separation equal to said linear travel distance, and said capacitor configured to provide a change of capacitance upon movement of said platform structure relative to said base member; and